

# Integrating Wind and Other Clean Generation in Mexico

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# The Evolution of Revolutions

- The Pioneers – first utility scale projects
  - Publicly funded starter projects (CFE, US DOE)
- Financial Proof of Concept – project financing
  - Land rights, permits, offtake, equipment supply and warranties all good enough to stand alone
  - Will be some ongoing subsidies since power markets ignore externalities
- First Wave of Deployment (1-10% RES)
  - Self supply in Mexico; Standard Offer PPAs in CA
- First Wave of Reforms (please ignore Enron)
  - CA RPS, Mexico's Energy Reforms
- Blast Off! – penetrations of 20-35-50-100%
  - Integration of RES at large, even dominating scale
  - Challenges of reliability, affordability, sustainability

## EDF EN North America KEY FIGURES

INSTALLED  
CAPACITY



3.2 GW

OPERATIONS &  
MAINTENANCE



10.5 GW

UNDER  
CONSTRUCTION



1.1 GW

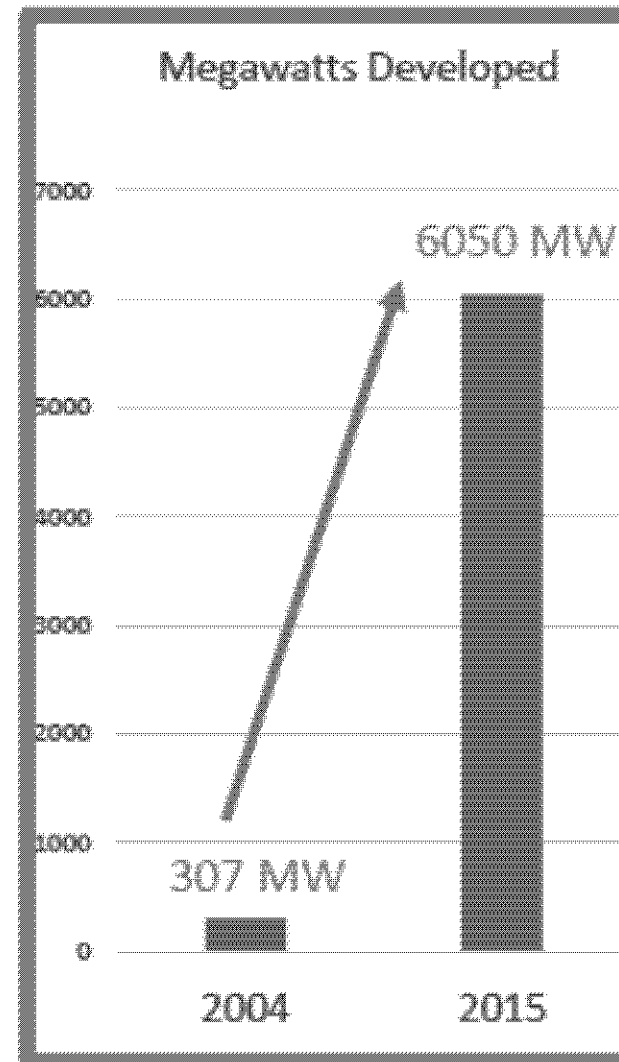
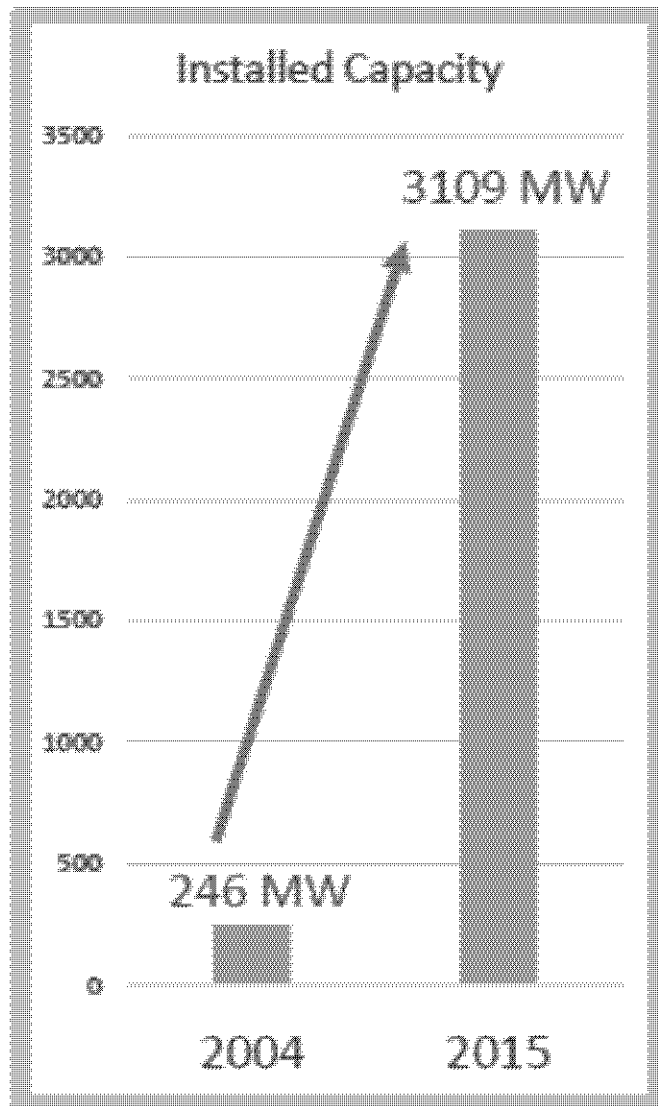
EMPLOYEES  
NORTH AMERICA



1,000

28 YEARS  
EXPERIENCE





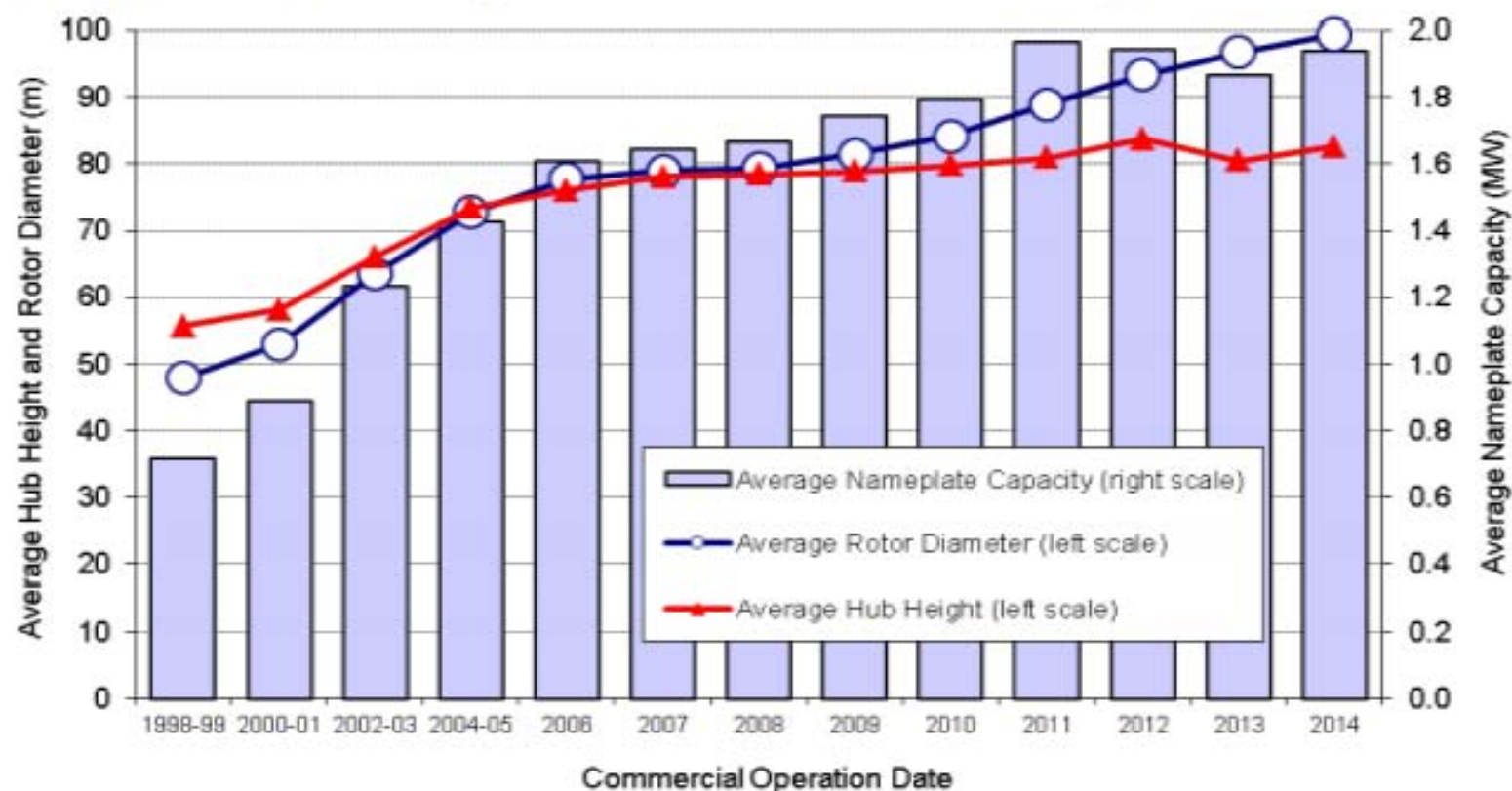
# System Scales

1. Components - Cells, inverters, blades, drive trains
  2. Generating Units - Turbines, PV modules
  3. Projects – 10-500 MW
  4. Resource & Control Areas
  5. Regional & National Grids
- ( 1 & 2 better understood than 3-5)

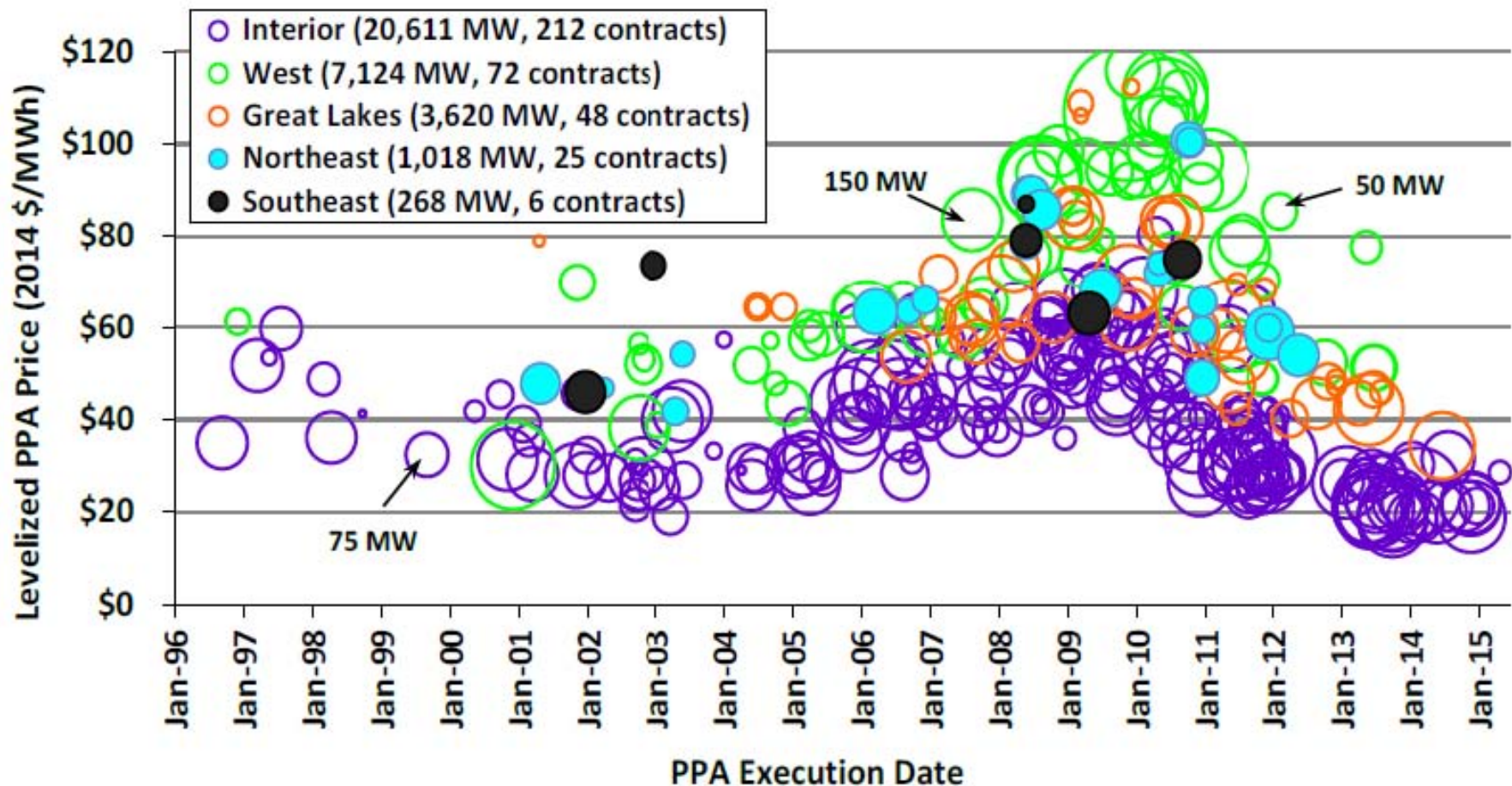
# Time Scales

1. Grid Transients – 1/10 cycle
2. Generator transients – gusts, clouds
3. Load Following
4. Annual Budgets
5. Resource Plans
6. Long Term Goals (35% by 2024, 50% by 2030)
7. VLT Plans & Projections (ALCOA 50 year plans, AB32 80% by 2050, COP21 <2C 2100)

# Turbine Nameplate Capacity, Hub Height, and Rotor Diameter Have All Increased Significantly Over the Long Term

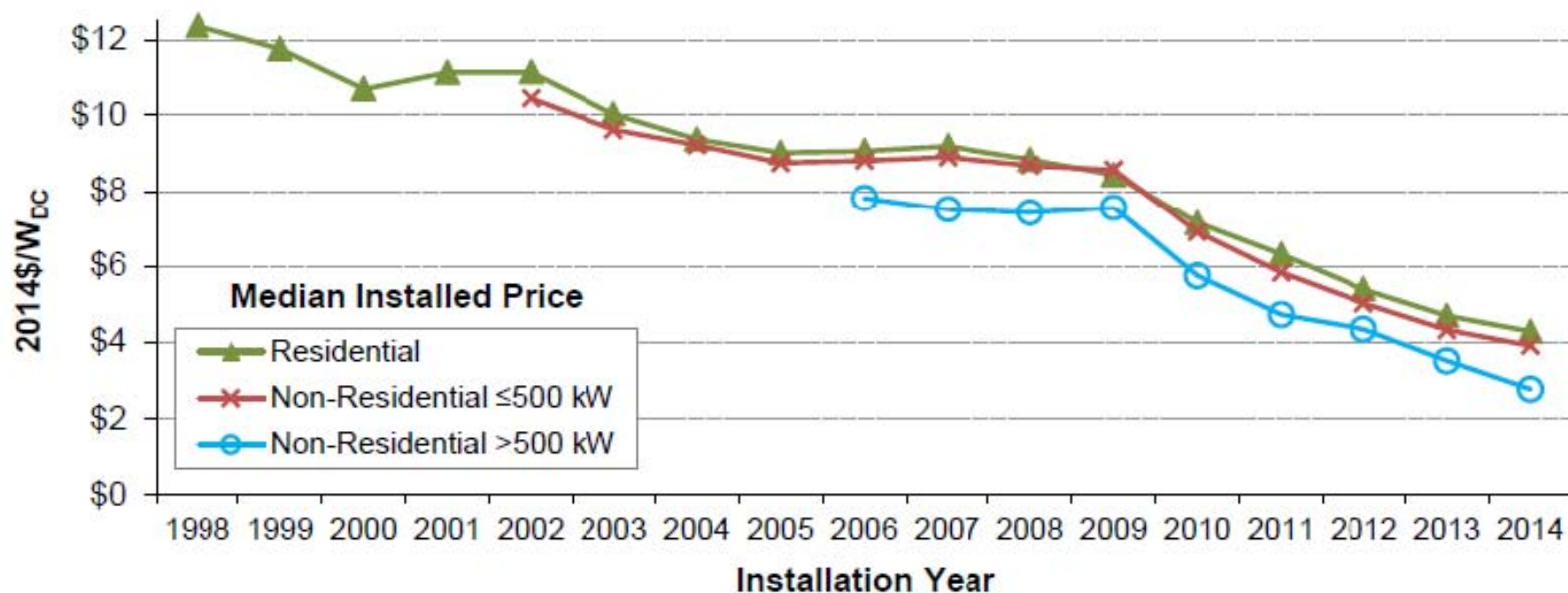


# Wind PPA Prices Have Reached All-Time Lows, Dominated by Interior Region



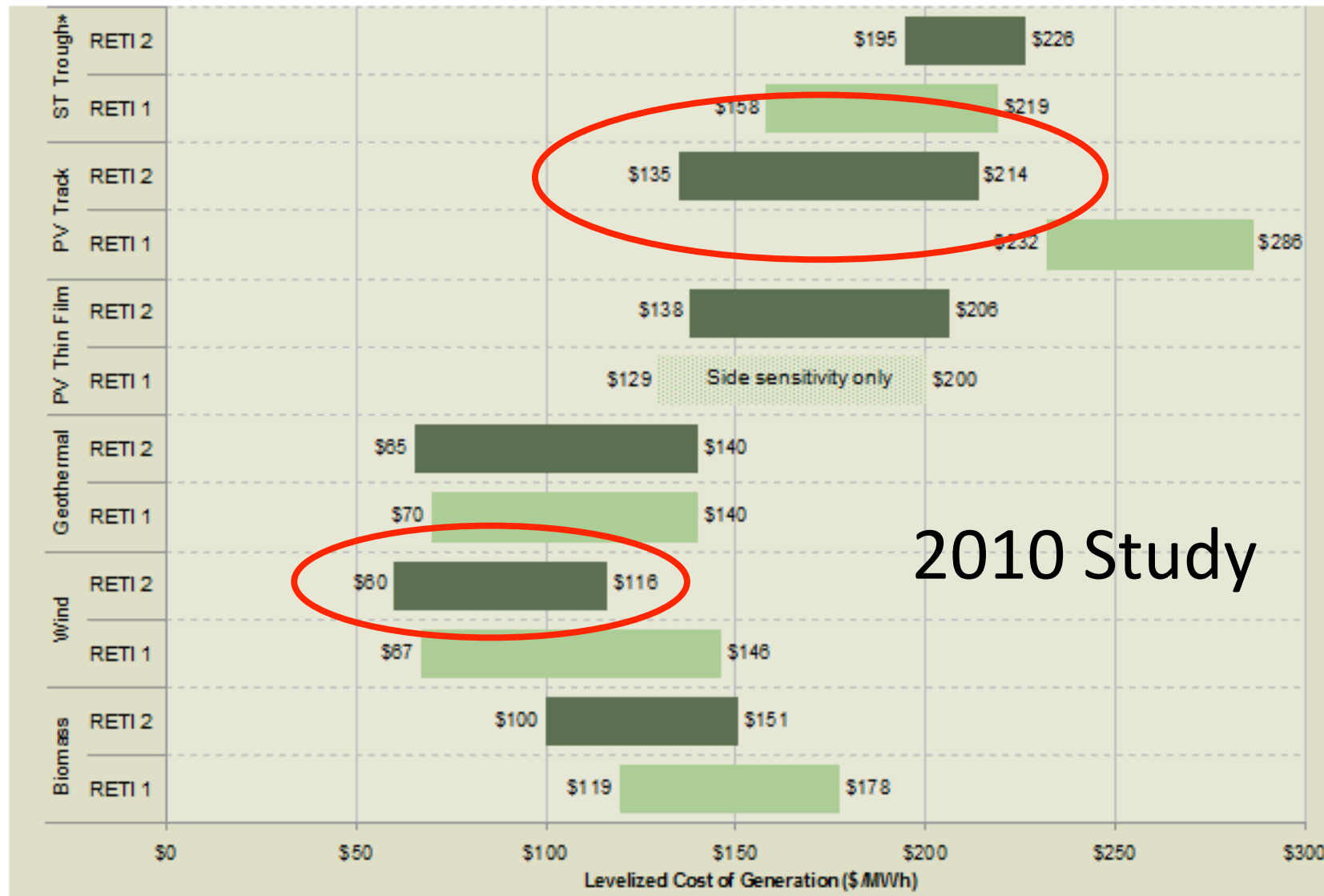
# Installed Prices Continued their Rapid Descent through 2014

National median installed prices in 2014 declined YoY by \$0.4/W (9%) for residential systems, by \$0.4/W (10%) for non-residential systems  $\leq 500$  kW, and by \$0.7/W (21%) for non-residential systems  $> 500$  kW



Note: Median installed prices are shown only if 20 or more observations are available for a given year and customer segment.

## Typical Cost of Generation Ranges: Current RETI Phase 2 Black & Veatch Proposal



## Unsubsidized Levelized Cost of Energy Comparison

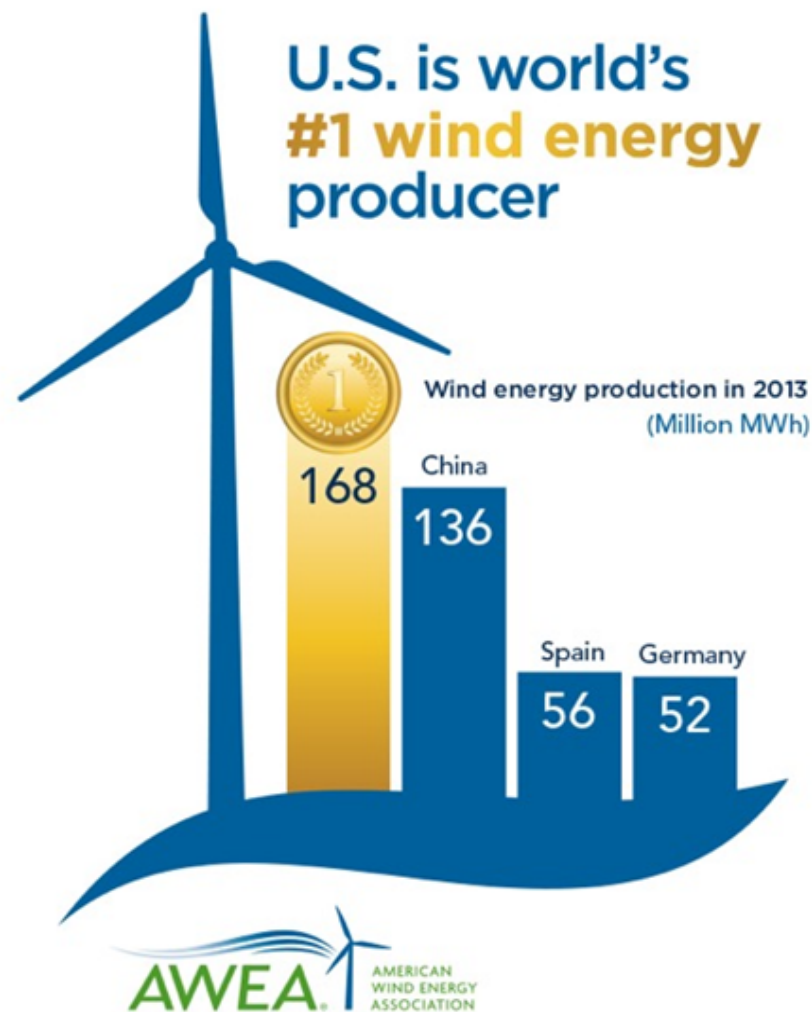
Certain Alternative Energy generation technologies are cost-competitive with conventional generation technologies under some scenarios; such observation does not take into account potential social and environmental externalities (e.g., social costs of distributed generation, environmental consequences of certain conventional generation technologies, etc.) or reliability-related considerations (e.g., transmission and back-up generation costs associated with certain Alternative Energy generation technologies)



Source: Lazard estimates

# What Gets Rewarded Gets Done

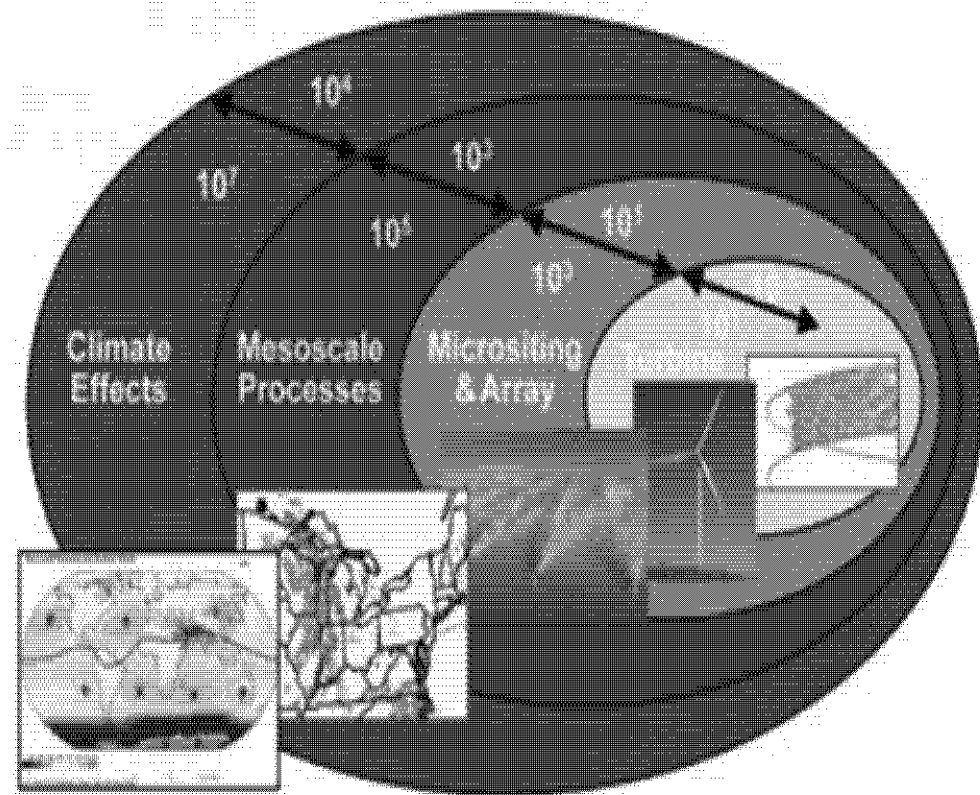
- US installations are driven by PRODUCTION incentives (PTC, project financing)
- China by INVESTMENT incentives
- US Wind Fleet produced 42% more TWH in 2014 with less than 60% of the MW (China TWH down 6%)
- Mexico also rewards production (Energy market, CELs, Carbon Credits)



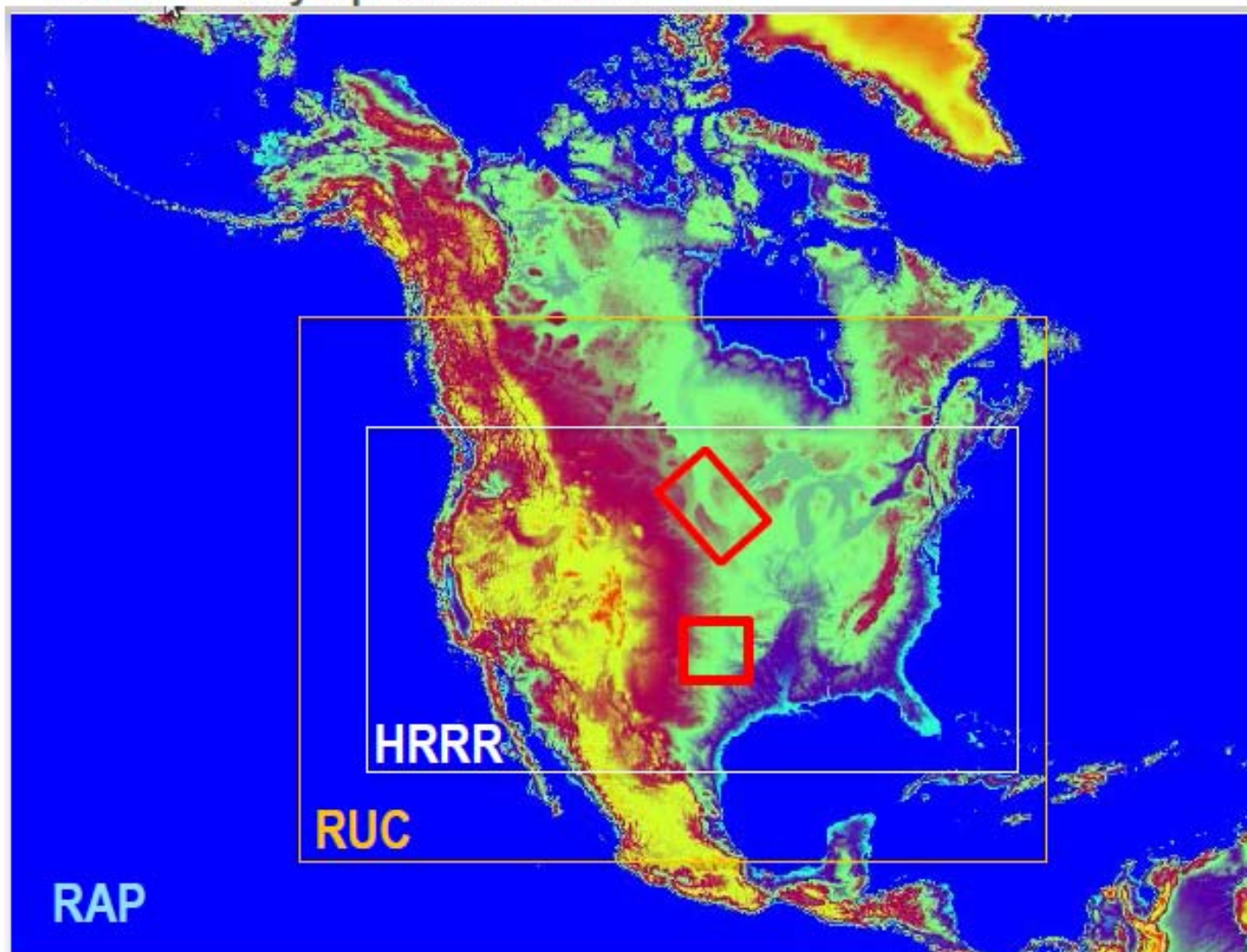
## 2.2 Science Challenge

The physics driving wind plant under-performance is an extremely complex problem that will be difficult to fully resolve.

Existing high fidelity models of an individual turbine operating under actual field conditions do not capture all of the appropriate underlying flow physics or dimensional scales necessary for a complete resolution of the turbine response. Fully resolving a fully integrated wind plant is orders of magnitude more difficult and requires modeling and assessment capabilities that do not exist today.



## NOAA hourly updated models



### **RUC (Rapid Update Cycle)**

13km resolution

No WFIP obs

assimilated

### **RAP (Rapid Refresh)**

13km resolution

WFIP obs assimilated

### **HRRR (High Res Rapid Refresh)**

3km resolution

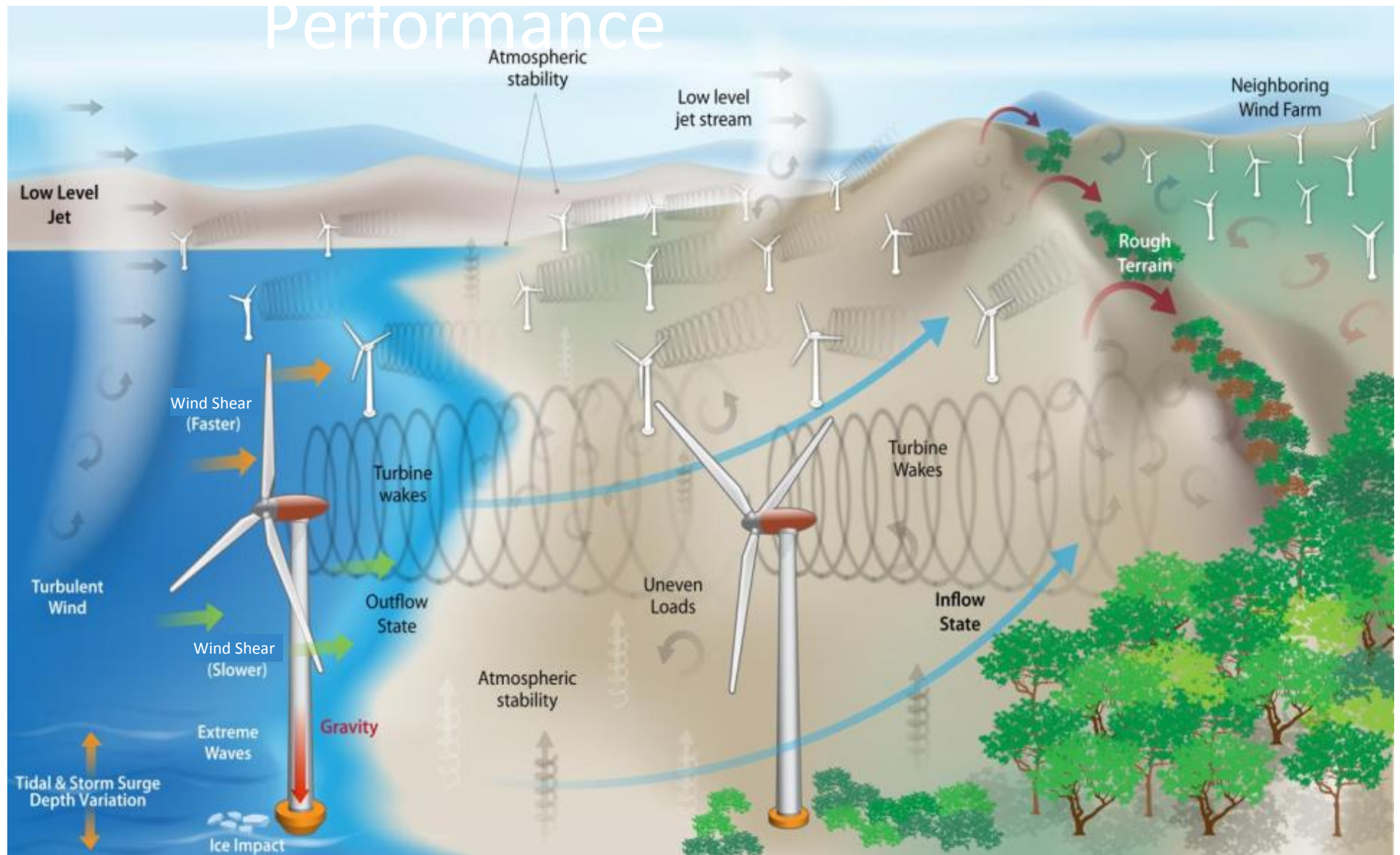
WFIP obs assimilated

### **Model Improvements:**

Data assimilation

PBL parameterization

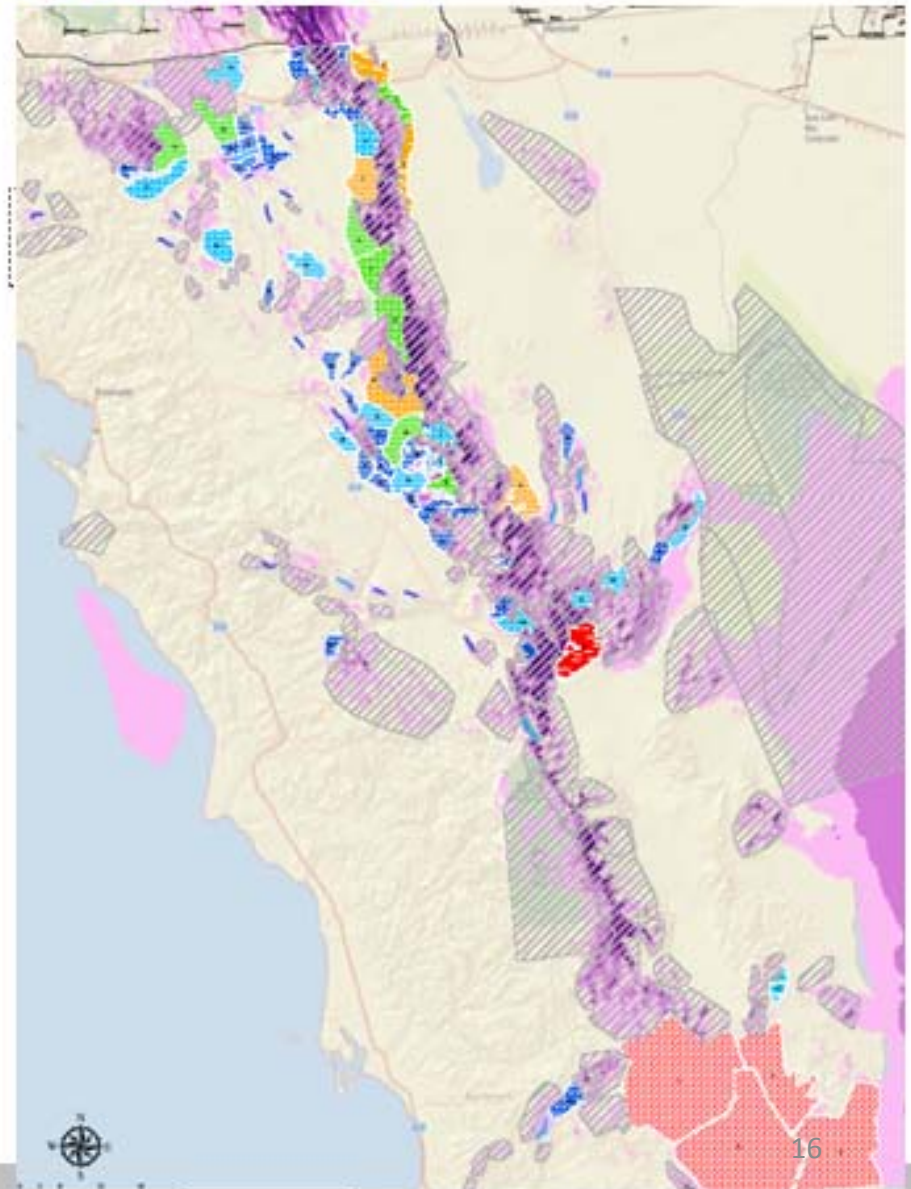
# Performance



## RETI: Baja Wind Energy Assessment

### Results

- 33,285 MW of technical potential
- Quantified 8,305 MW as developable potential (25% of technical)
- 89 projects
- Average capacity factor: 35%
- Average capital cost: \$2,450 / kW



# The California 2030 Low-Carbon Grid Study

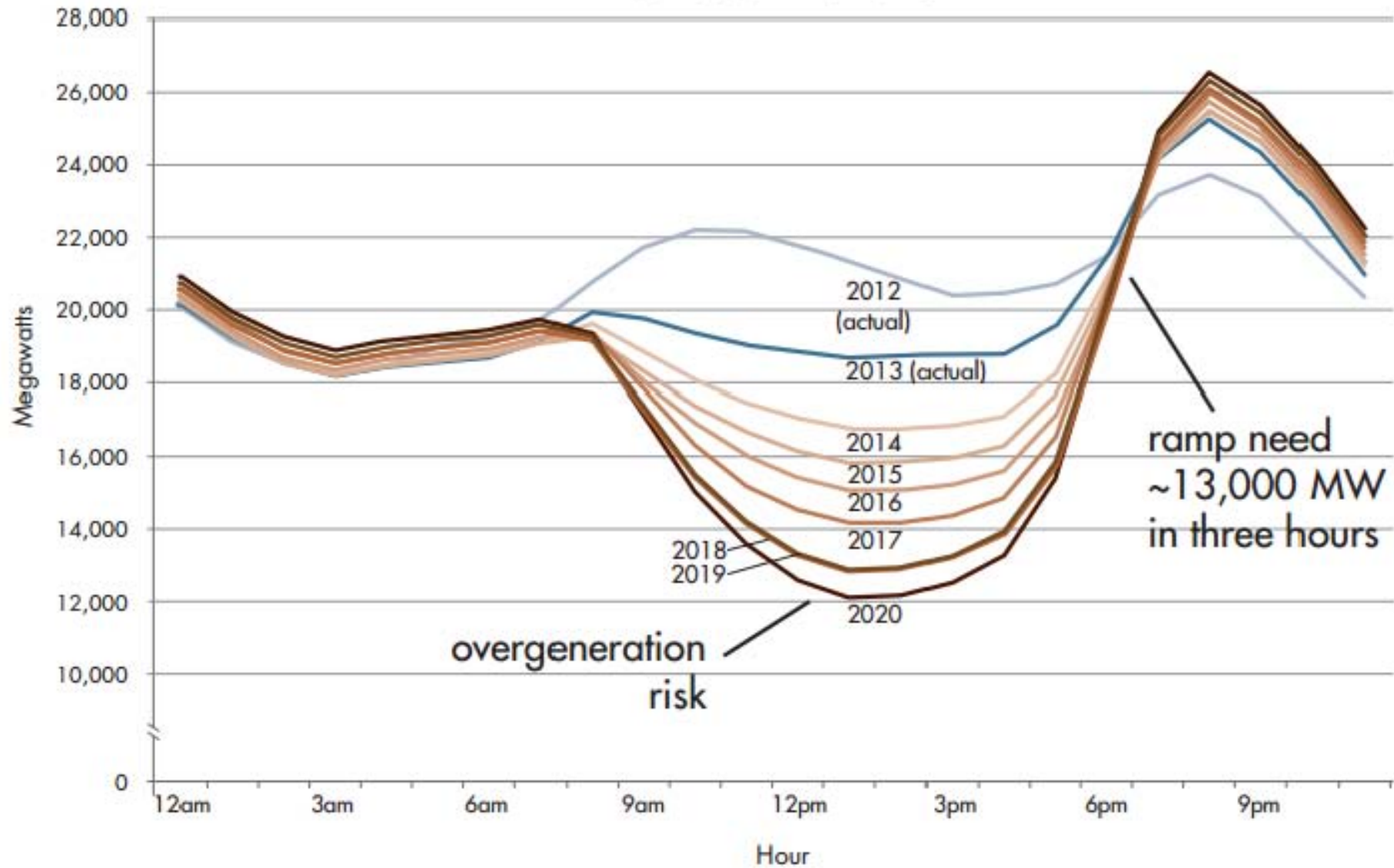
## Phase I Results Overview

*November, 2014*



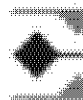
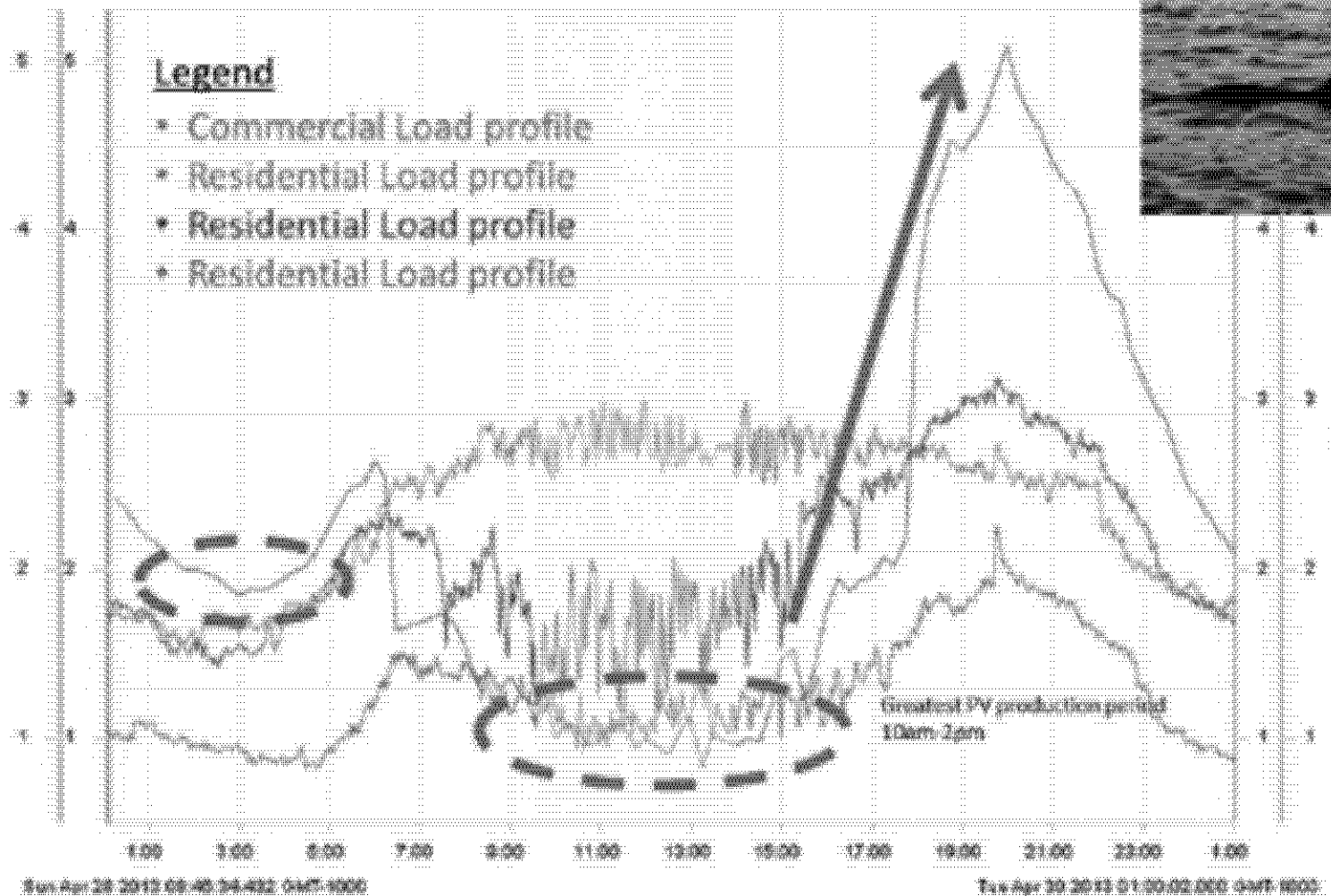
**Figure 2: The duck curve shows steep ramping needs and overgeneration risk**

Net load - March 31



# Trending Hi-Pen Circuits (12kV) – Loch Ness Profile

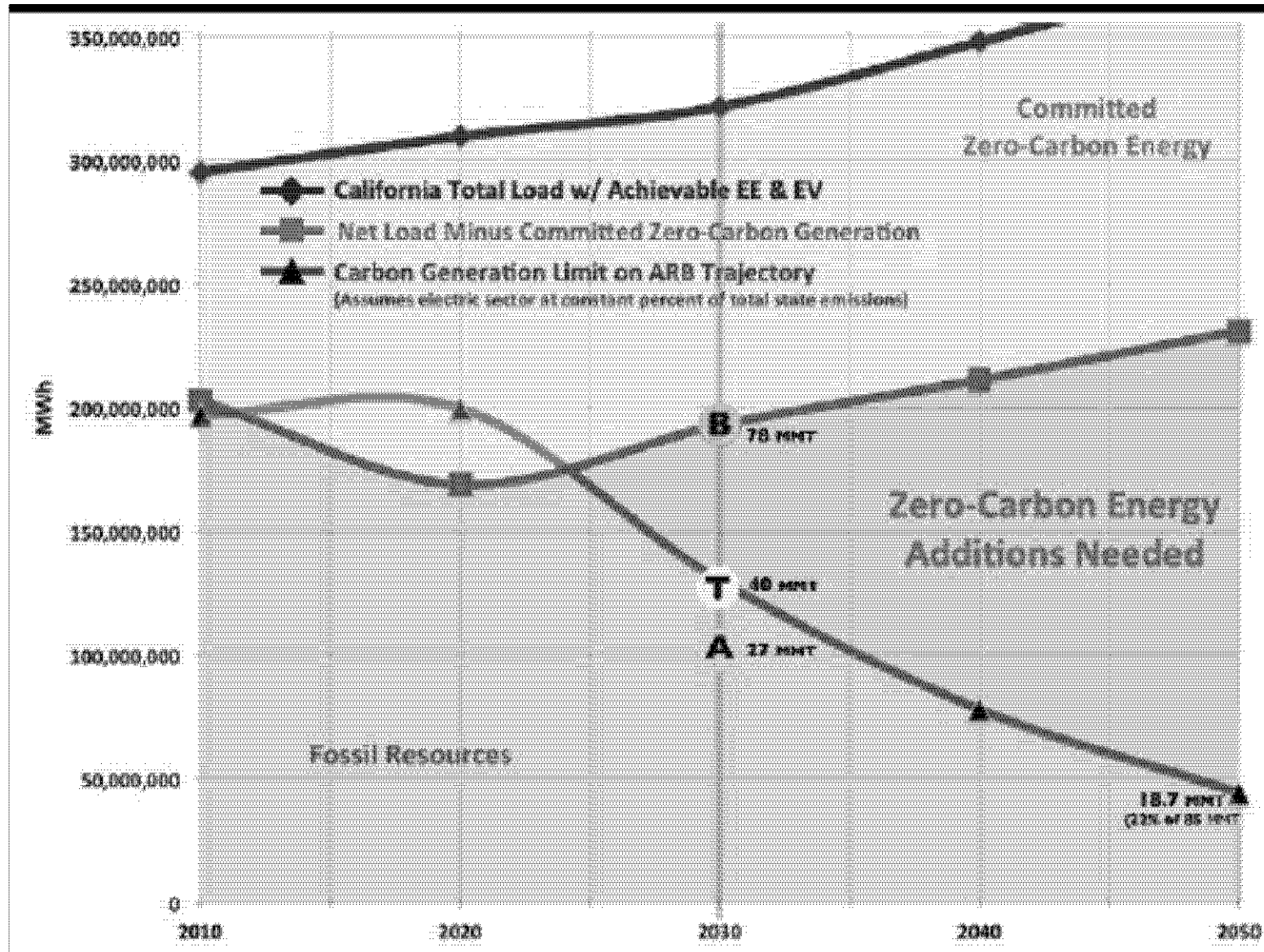
Time Series | Histograms | Scatter Plot



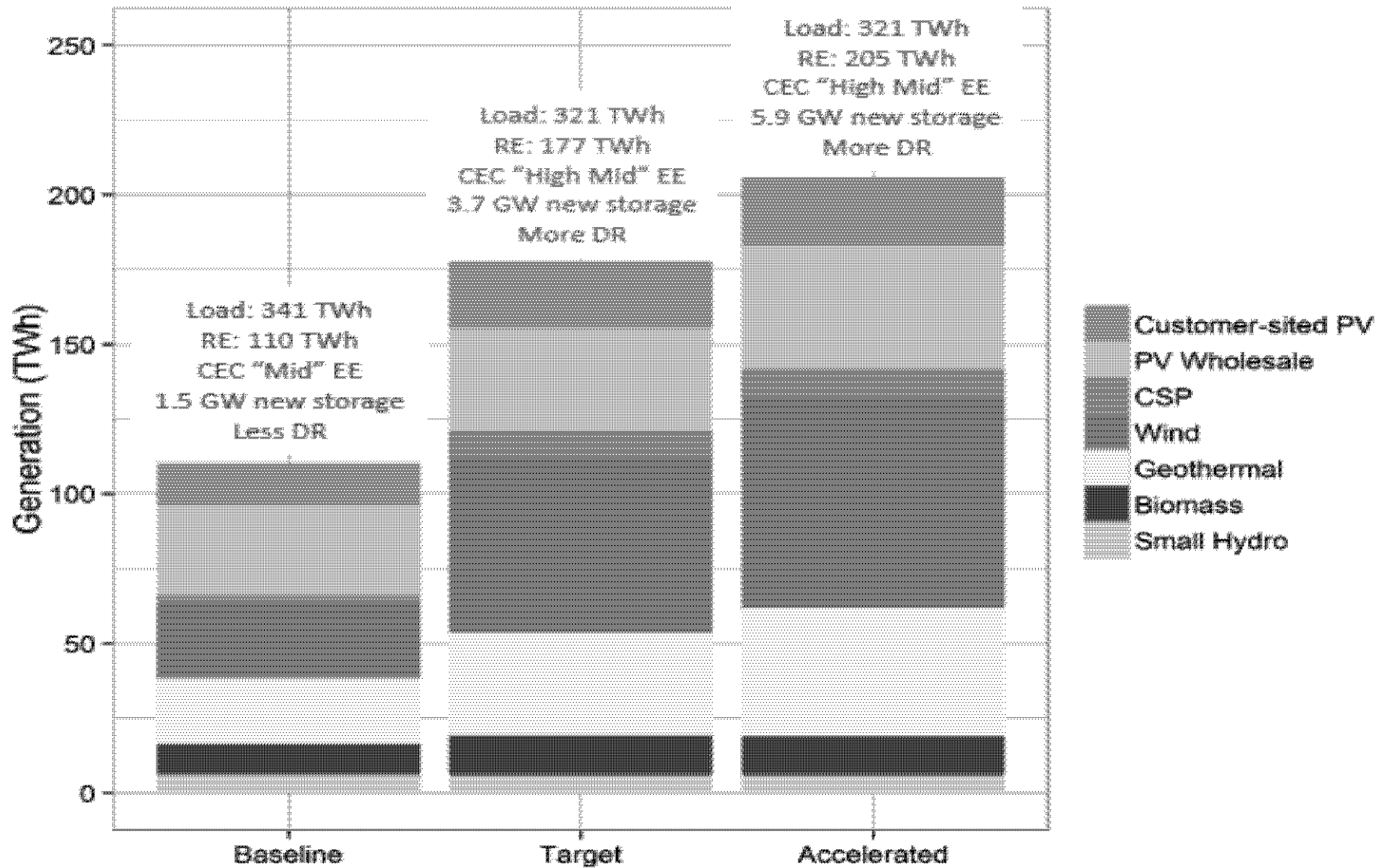
min hour day week 4w 52w crop expand left right

Source: HECO

# 2030 Scenarios on the Path to 2050



# Diversified Supply Side

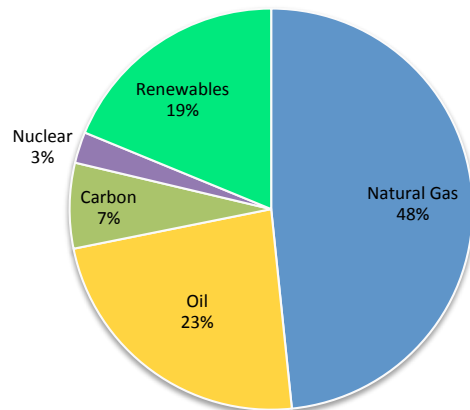


# Key Findings for California

- **Deep electric system carbon reduction can be achieved at low net cost and is a key step towards meeting 2050 goals.**
- **A portfolio approach is critical:**
  - Regional coordination
  - Energy efficiency and demand response
  - Diverse zero-carbon resources
  - Minimal new transmission
  - Highly efficient natural gas
- **Current grid practices prevent deep carbon reductions at reasonable cost.**
- **Ageing electric infrastructure must be replaced**
  - An opportunity to make carbon-based decisions on replacement power

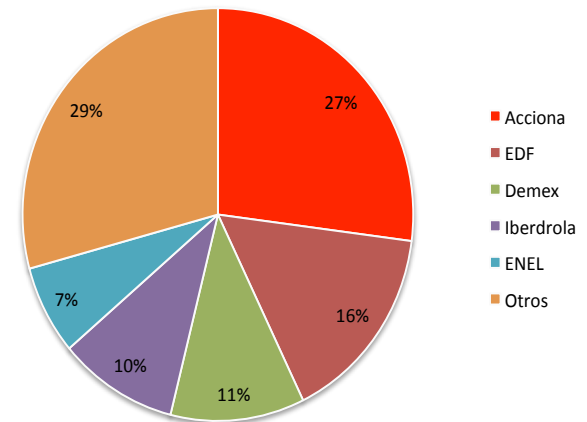
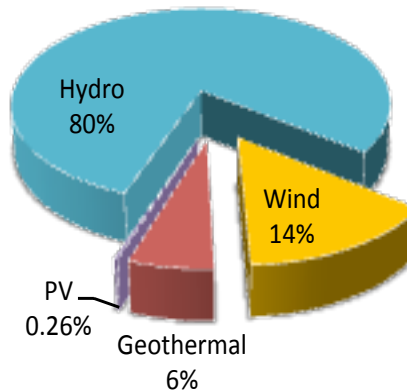
# Market overview (2014)

## ✿ Mexican Generation mix (2014)



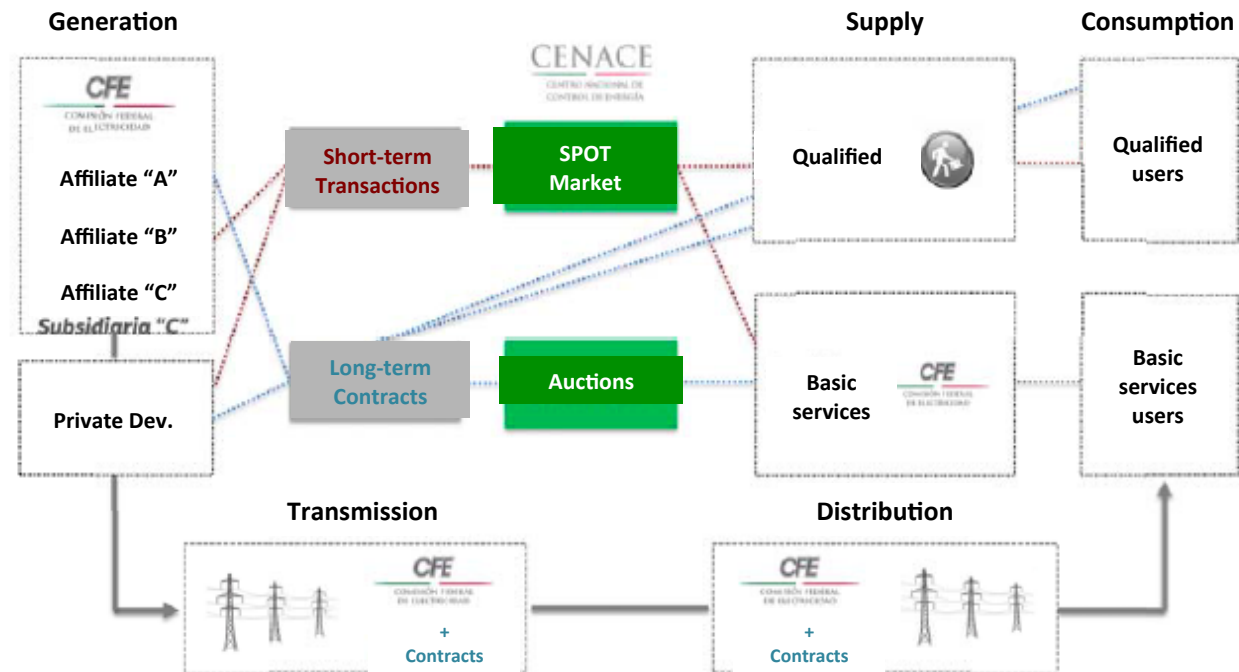
## ✿ Renewables mix in Mexico – 14,500 MW (2014)

## ✿ Market share for wind – 2,100 MW (2014)



# New Market perspective

🌸 A “view” of the new Mexican market:



# Looking Ahead

- Mexico very attractive RES market in long term
  - Excellent solar, wind, hydro, geothermal resources
  - Growth in demand, need to replace older plants
- Challenges
  - Completing the reforms – uncertainty in transition period inhibits investment
  - CEL market holds great promise – but need to tie CEL credits to other environmental benefits to reward going beyond 35%
  - Opportunities for cross border commerce and coordination.